Time interval measurement method for laser distance measurement

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Abstract of **DE19703633**

The method involves triggering a first charging process of a capacitor (C1) at the beginning of a time interval or at appearance of a first event (T1). The first charging process of the capacitor is terminated in dependence on a climbing or falling flank of the clock signal delivered by a clock generator. At completion of the time interval or at appearance of a second event (T2), a second charging process of a capacitor (C2) is triggered, and the second charging process of the capacitor is terminated at a climbing or falling flank of the clock signal. The amount of clock pulses between the clock flank terminating the first charging process and that terminating the second charging process is determined using a digital counter. The time interval is calculated through addition of the duration of the first charging process and the counted clock pulses, and following subtraction of the duration of the second charging process.

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[54] Title of Invention: Target-seeking method and device which can operate with a laser rangefinder having a false alarm rate

[57] Abstract

This invention relates to a target-seeking method and device which can operate with a laser rangefinder having a false alarm rate, the concept of which is mainly based on utilizing randomly occurring clutter, such that the same measuring step is repeated many times and the signals obtained are subjected to statistical treatment, after which the statistical information seeks out the target object signal, firstly emitting an exploratory laser wave to the object for measurement and then receiving the echo wave from the exploratory laser wave together with the accompanying clutter and recording the number of times on which reflection waves and the accompanying clutter appear corresponding to different sequences; after repeating the above steps a number of times, statistical information is obtained, and based on this statistical information, the range to the object for measurement is calculated and the accompanying clutter is discarded.

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Claims

1. A target-seeking method which can operate with a laser rangefinder having a false alarm rate, characterized by inclusion of the following steps:

A. Emission of a laser signal: a laser emitter emits a predetermined number of pulsed laser signals in a predetermined sequence;

B. A received reflected laser light signal: a light receiver receives the laser light signal reflected from the target object together with clutter produced by the outdoor daylight, and a feedback control circuit varies the threshold voltage of a comparator, so that the light receiver operates at a fixed false alarm rate;

C. Information conversion: a serial-to-parallel temporary storage device operating at a high sampling rate converts the serial digital signal of fixed pulse width output by the light receiver into a parallel information output;

D. Information storage: with an N - 1 parallel-to-serial multiplexer controlled by a low-speed decoding signal, the locked parallel information is read in sequence by a microprocessor, and the microprocessor stores this serial information in sequence in its storage device;

E. Information integration: the new serial information obtained at the time of each emission is stored in sequence in the storage device, and this new information together with the original storage device information completes an accumulation function, which is to say that integration is carried out on the contents of the storage device;

F. Target-seeking: when a predetermined number of emissions is reached, the maximum value in the search and storage device and the location corresponding to it are used, such that the address corresponding to the maximum value in this storage device is the range to the target object.

2. A target-seeking device which can operate with a laser rangefinder having a false alarm rate, characterized by including:

A laser emitter, used for emitting pulsed laser light;

A pulse producer used for producing the pulse signal required by the system;

A fixed false alarm rate light receiving element which makes use of the clutter level received by the light receiver, with a servo control loop to adjust the threshold voltage of the high-speed comparator, thus achieving a highly sensitive light receiver with a fixed false alarm rate;

A range measuring unit, utilizing the pulse wave serial reflection and an accumulation method to achieve the finding of the range to the target object in the presence of clutter.

3. A target-seeking device which can operate with a laser rangefinder having a false alarm rate according to Claim 2, characterized by: the fixed false alarm rate element therein including: a light receiver, which converts the light signal received into a voltage signal; a high-speed comparator, such that when the input signal is greater than the predetermined threshold voltage it emits a series of pulse waves; a one-shot circuit used for producing a digital pulsed series having a fixed pulse wave width; a gate control counter which accumulates the clutter pulse wave quantity in a predetermined gate time segment; a D/A converter used for converting the quantity calculated by the counter into an analogue signal voltage; an integrator, used for carrying out integration processing on the potential difference between the output voltage after digital-to-analogue conversion and the reference voltage, the output of the integrator being used to adjust the critical voltage of the high-speed comparator to complete the servo control loop having a fixed false alarm rate.

4. A target-seeking device which can operate with a laser rangefinder having a false alarm rate according to Claim 2, characterized by: the range measuring element therein including: an information locking device, which locks the input pulse wave series in a parallel D-type demultiplexer under high frequency conditions; a multiplexer which converts the parallel locked information to serial information under low-frequency conditions; a main pulse producer used to provide the main pulse for the microprocessor; a microprocessor used to reflect the information to the storage device and implement a program to search out the range to the target and discard the invalid ranges measured; a storage device used for storing the locked information at the designated address.

5. A target-seeking device which can operate with a laser rangefinder having a false alarm rate according to Claim 2, characterized by: the fixed false alarm rate light receiver element therein including a transfer impedance amplifier used for converting the input light signal into a voltage signal output; a high-speed comparator connected to the transfer impedance amplifier, the transfer impedance amplifier output signal being transmitted to the high-speed comparator; a one-shot circuit connected to the high-speed comparator and used for obtaining and outputting a digital pulse series at a fixed pulse width, this one-shot circuit output signal being controlled by a pulse signal via an AND gate, used for removing the instantaneous interference between the laser emission and light receiver, this AND gate output signal then being fed into the information locking device and gate control counter, the gate control counter being used to calculate the clutter pulse wave quantity within a gate time segment.

Description

Target-Seeking Method and Device Which Can Operate With a Laser Rangefinder Having a False Alarm Rate

The present invention relates to a target-seeking method and device which can operate with a laser rangefinder having a false alarm rate, and in particular refers to a laser rangefinding method and device which can increase the measured range of the target without increasing the laser emission power to improve the precision of range measurement.

A laser rangefinder (Laser Range Finder) is an important device for range measurement and customarily used rangefinders use a pulsed (pulse) laser emitter to emit a laser pulse (laser pulse) of approximately 10 ns - 20 ns to a target. The laser signal reflected by the target object is received by a laser receiver (laser receiver), and the range is calculated by means of the following formula (1):

$$T_d = 2L/C \tag{1}$$

In formula (1), L represents the range between the laser rangefinder and the target object, C represents the speed of light, and T_d represents the time delay between the emitted laser pulse and the received laser pulse. By measuring T_d a precise range can be calculated according to formula (1). In order precisely to measure T_d, it is necessary to strengthen the laser emission power as much as possible or eliminate the clutter produced by daylight and sunlight received by the laser receiver. US Patent 3,644,740 disclosed a receiver circuit which obtained a false alarm by controlling the circuit bias of the receiver circuit and thus improved the signal-clutter ratio of the receiver circuit. US Patent 4,569,599 disclosed a counting (counting) control technology used for detecting the range signal. US Patent 4,770,526 disclosed a technology which increased the range detection result value by amplifying the time delay signal. Furthermore, a digital distance measuring technology was also disclosed in US Patent 3,959,641, used for lowering the critical voltage of the laser receiver, thus increasing the measured range.

In order to cope with different circumstances, US Patent 5,612,779 also disclosed a design which could automatically adjust the threshold voltage (Threshold Voltage). In this prior art,

the threshold voltage could vary with the signal strength reflected from the target object, enabling the establishment of a threshold voltage between the clutter and the target signal strength in different environments. The main effect of the above-mentioned patents was in increasing the measured range and the precision.

The main objective of the present invention is to provide a target-seeking method and device which can operate with a laser rangefinder having a false alarm rate, and it proposes a novel method different from the prior art disclosed above which uses digital integration technology to filter out the clutter, enabling a laser rangefinder through the present invention to seek out the signal from the target object in the presence of clutter, and so the laser rangefinder of the present invention can jointly meet the requirements of increasing the measured range and raising the precision.

The present invention relates to a target-seeking method which can operate with a laser rangefinder having a false alarm rate, which includes the following steps: A. Emission of a laser signal: a laser emitter emits a predetermined number of pulsed laser signals in a predetermined sequence; B. A received reflected laser light signal: a light receiver receives the laser light signal reflected from the target object together with clutter produced by the outdoor daylight, and a feedback control circuit varies the threshold voltage of a comparator, so that the light receiver operates at a fixed false alarm rate; C. Information conversion: a serial-to-parallel temporary storage device operating at a high sampling rate converts the serial digital signal of fixed pulse width output by the light receiver into a parallel information output; D. Information storage: with an N - 1 parallel-to-serial multiplexer controlled by a low-speed decoding signal, the locked parallel information is read in sequence by a microprocessor, and the microprocessor stores this serial information in sequence in its storage device; E. Information integration: the new serial information obtained at the time of each emission is stored in sequence in the storage device, and this new information together with the original storage device information completes an accumulation function, which is to say that integration is carried out on the contents of the storage device; F. Target-seeking: when a predetermined number of emissions is reached, the maximum value in the search and storage device and the location corresponding to it are used, such that the address corresponding to the maximum value in this storage device is the range to the target object.

The present invention relates to a target-seeking device which can operate with a laser rangefinder having a false alarm rate, the device including: A laser emitter, used for emitting pulsed laser light; a pulse producer used for producing the pulse signal required by the system; a fixed false alarm rate light receiving element which makes use of the clutter level received by the light receiver, with a servo control loop to adjust the threshold voltage of the high-speed comparator, thus achieving a highly sensitive light receiver with a fixed false alarm rate; a range measuring unit, utilizing the pulse wave serial reflection and an accumulation method to achieve the finding of the range to the target object in the presence of clutter.

The fixed false alarm rate element therein includes: a light receiver, which converts the light signal received into a voltage signal; a high-speed comparator, such that when the input signal is greater than the predetermined threshold voltage it emits a series of pulse waves; a one-shot circuit (one-shot circuit) used for producing a digital pulsed series having a fixed pulse wave width; a gate control counter which accumulates the clutter pulse wave quantity in a predetermined gate time (gating time) segment; a D/A converter used for converting the quantity calculated by the counter into an analogue signal voltage; an integrator, used for carrying out integration processing on the potential difference between the output voltage after digital-to-analogue conversion and the reference voltage, the output of the integrator being used to adjust the critical voltage of the high-speed comparator to complete the servo control loop having a fixed false alarm rate.

The range measuring element therein includes: an information locking device, which locks the input pulse wave series in a parallel D-type demultiplexer under high frequency conditions; a multiplexer which converts the parallel locked information to serial information under low-frequency conditions; a main pulse producer used to provide the main pulse for the microprocessor; a microprocessor used to reflect the information to the storage device and implement a program to search out the range to the target and discard the invalid ranges measured; a storage device used for storing the locked information at the designated address.

The fixed false alarm rate light receiver element therein includes a transfer impedance amplifier used for converting the input light signal into a voltage signal output; a high-speed comparator connected to the transfer impedance amplifier, the transfer impedance amplifier output signal being transmitted to the high-speed comparator; a one-shot circuit connected to the high-speed comparator and used for obtaining and outputting a digital pulse series at a

fixed pulse width, this one-shot circuit output signal being controlled by a pulse signal via an AND gate, used for removing the instantaneous interference between the laser emission and light receiver, this AND gate output signal then being fed into the information locking device and gate control counter, the gate control counter being used to calculate the clutter pulse wave quantity within a gate time segment.

In order that the characteristics of the present invention be better understood, there follows a relatively optimum practical example in combination with the figures, which are explained as follows, wherein:

Figure 1 is a schematic diagram of the steps of a relatively optimum practical example of this invention;

Figure 2 is a sequence chart of a relatively optimum practical example of this invention, which shows the relations between the laser receiver at any two laser emissions, the output signal SO1 of the transfer impedance amplifier, the output SO2 of the one-shot circuit and the sample signal T_{latch};

Figure 3 shows the situation with the storage device of the microprocessor of a relatively optimum practical example of this invention at any two laser emissions, and the figure shows the storage addresses and the internally stored information corresponding to the first laser emission and the eighth laser emission;

Figure 4 is an operational flow chart of a relatively optimum practical example of this invention;

Figure 5 is a schematic diagram of the laser rangefinder system of a second relatively optimum practical example of this invention;

Figure 6 is a schematic diagram of the laser receiver system of a second relatively optimum practical example of this invention;

Figure 7 shows the signals at different locations in the schematic diagram of the laser rangefinder system of a second relatively optimum practical example of this invention; TX: laser emitter trigger signal, SO2: one-shot (One-Shot) circuit output signal, TG1: internal reflection screened signal, TG2: gate control signal, T_{latch}: sample pulse signal;

Figure 8 is a schematic diagram of the digital signal processing in a second relatively optimum practical example of this invention.

Referring to Figure 1, a target-seeking method which can operate with a laser rangefinder having a false alarm rate as provided by a relatively optimum practical example of this invention includes the following steps:

A. Emission of a laser signal: a laser emitter emits a predetermined number of pulsed laser signals in a predetermined sequence, wherein the pulse width of the laser signal is 10 - 20 ns;

B. A received reflected laser light signal: a light receiver receives the laser light signal reflected from the target object together with clutter produced by the outdoor daylight, and a feedback control circuit varies the threshold voltage of a comparator, so that the light receiver operates at a fixed false alarm rate;

C. Information conversion: a serial-to-parallel temporary storage device operating at a high sampling rate converts the serial digital signal of fixed pulse width output by the light receiver into a parallel information output;

D. Information storage: with an N - 1 parallel-to-serial multiplexer controlled by a low-speed decoding signal, the locked parallel information is read in sequence by a microprocessor, and the microprocessor stores this serial information in sequence in a storage device;

E. Information integration (accumulation): the new serial information obtained at the time of each emission is stored in sequence in the storage device, and this new information together with the original storage device information completes an accumulation function, which is to say that integration is carried out on the contents of the storage device;

F. Target-seeking: when a predetermined number of emissions is reached, the maximum value in the search and storage device and the location corresponding to it are used, such that the address corresponding to the maximum value in this storage device is the range to the target object.

Figure 2 shows a comparison of the transfer impedance amplifier output signal SO1 (shown in Figures 2a and c) and the one-shot circuit output signal SO2 (shown in Figures 2b and d) at the time of any two laser emissions; the SO1 signal includes different vibration amplitudes, of which the signal on the time axis Ts is the target signal, and the signals on other time axes are clutter; the SO2 signal is the fixed pulse width standard digital output standard position; when the signal SO1 is greater than the predetermined threshold voltage, the SO2 outputs a fixed pulse width TTL output signal, and the synchronized sample pulse signal T_{latch} is shown in Figure 2e; for different emissions, the target signal in SO2 emerges on the fixed time axis Ts while the clutter pulse waves appear at different locations. The sample pulse signal T_{latch} is used to sample the signal SO2, and so SO2 may be sequentially locked in the serial-to-parallel temporary storage device by the sample pulse signal T_{latch}.

Figure 3 shows the information stored at the storage device addresses at the times of the first and eighth laser emissions; under the circumstances at different sampling times when T_{latch} = T1, T2, T3, T4 … , the corresponding addresses are set at ranges of 1 m, 2 m, 3 m, 4 m … , and the information contained at the corresponding addresses is the information D_0 - D_N in the output signal SO4 from the information locking device. Supposing the target appears at T_{latch} = T500, then when the first laser emission occurs, the content of the storage device at the address 01FCH is the information locking device output signal SO4 information $D_{499} = 1$, but the storage device also has information stored at different addresses, and so at the time of the first laser emission the target signal has not yet been found. When the eighth emission occurs, the target corresponding to the position 01FCH is situated at 500 m and the locked time is T500. The contents of the storage device are accumulated to 8, but the accumulated values of the contents at other addresses are all lower than 8, and so the target signal can be found by seeking the maximum value in the storage contents and its corresponding address. If the number of laser emissions is increased, the quantitative difference between the value contained at the target address and the values at the clutter addresses will increase; the target object can therefore more easily be found.

Figure 4 is a program flow chart of this invention, wherein the number of emissions N1 is pre-set at 1 and the total number of emissions is pre-set at 0 (step a); the total number of emissions T is 10N1 + T (step b), wherein there is a sequential increase in the quantity representing each group of 10 emissions, and the information represented at the designated address in the storage device is calculated T times, after which a search is carried out for the maximum value in the contents of the storage device and the corresponding address (step c).

The value of the ratio (Max_Value)/T is found, being the number of times the target signal appears within T times, and the value of the ratio (Max_Value)/T is compared with the pre-set value Nth (step d); if the value of (Max_Value)/T is greater than the pre-set value Nth, the address corresponding to the output is the target range; if the value of (Max_Value)/T is less than the pre-set value Nth, a further occasion of T laser emissions is carried out, and the number of emissions in the cycle is increased by 1 (N1 = N1 + 1) (step f); the pre-set value Nth is the maximum number of emissions, and if N1 - N_{set} is equal to 0, the laser emission function is terminated.

It can be seen from the steps described above that this invention utilizes a laser receiver with a fixed false alarm rate to increase the sensitivity of the laser receiver, and it utilizes a serial reflection address method to seek out the target signal in the presence of clutter; it filters out the clutter from the signal and clutter by a digital integration method and amplifies the signal, thus achieving an increase in the measured range by increasing the number of emissions without increasing the emission power, thus increasing the measurability of the target object.

Referring to Figures 5 to 6, a second relatively optimum practical example of this invention provides a laser rangefinder device 1, which is a practical application of the method described in the previous practical example. Figure 5 shows the laser rangefinder device 1, mainly comprising a laser emitter 10, a fixed false alarm rate element 20 used to ensure that the laser receiver operates at a fixed false alarm rate, a range measuring element 30, and a pulse producer 40, wherein:

The laser emitter 10 is used to emit a group of laser light pulses having a pulse width of 10 - 20 ns;

The fixed false alarm rate element 20 includes: a light receiver 21, a gate control counter 23, a D/A converter 24, and a differential integrator 22;

The light receiver 21 is used to receive the light signal, and the light signal received includes the laser light signal reflected from the target object together with clutter produced by the outdoor (sun) light. The output signal SO3 of the light receiver 21 is a sequence of digital pulses having a fixed pulse width, and the digital pulse sequence contains a target signal and many accompanying clutter pulse sequences, wherein the output signal SO3 of the light receiver 21 is fed to the information locking device (31) to be used for range measurement. The signal SO3 is also fed into the gate control counter 23 to be used for controlling the fixed false alarm rate;

The gate control counter 23 is controlled by the pulse signal TG2 and is used to obtain the total number of pulse waves occurring within the gate-in (gate-in) time, the total number of pulse waves appearing within the (gate-in) time representing the false alarm rate of the receiver circuit;

The D/A converter 24 (digital to analogue) is used to convert the output of the gate control counter 23 into an analogue voltage, and the differential integrator 22 is used to carry out integration treatment on the potential difference between the reference voltage V_{REF} and the output voltage of the D/A converter 24, the output of the differential integrator 22 being used to adjust the critical threshold voltage value V_{TH} of the high-speed comparator 212 (refer to Figure 6) in the light receiver 21 to form a feedback control system; when this feedback control system is operating normally, the function of the differential integrator 22 enables the potential difference between the reference voltage V_{REF} and the output voltage of the D/A converter 24 to be a maintained at zero or maintained at an extremely low value;

The range measuring element 30 includes: an information locking device 31, a multiplexer 32, a main pulse production device 34, a microprocessor 35 and a storage device 33;

The information locking device 31 receives the output signal SO3 produced by the light receiver 21, and this information locking device 31 comprises a serial-to-parallel D-type demultiplexer; the speed of locking (Latch) of the information lock is T_{latch}, and so the resolution of the range measurement is controlled by the frequency of T_{latch}; with a precision

of 1 m, the T_{latch} frequency is approximately 75 MHz; to obtain even higher precision, it must be matched by a higher frequency T_{latch}; the maximum number of parallel outputs from the D-type demultiplexer limits the maximum range for measurement by the laser rangefinder, and as regards a range measurement capability of 1 km and a precision of 1 m, the parallel D-type demultiplexer number required is 1000, and with a precision of 2 m, the parallel D-type demultiplexer number falls to 500, and the locking frequency can be lowered to (75/2) MHz;

The multiplexer 32 is used to convert the parallel D-type output signal SO4 to a serial signal SO5, the transmission speed of the information in the serial signal SO5 being controlled by the pulse signal T_{mux}, the T_{mux} speed being far lower than T_{latch}, and the serial information output by the multiplexer 32 signal SO5 is read by the microprocessor 35. The T_{latch} frequency is a low-frequency signal, and the T_{latch} frequency in this practical Example is 200 Hz, far lower than the T_{latch} frequency of 75 MHz; at each laser emission, the serial information SO5 is transmitted to the storage element 33 of the microprocessor 35, the software of the microprocessor 35 controlling the address at which the information is stored in the storage device element 33;

The pulse producer 40 is controlled by the microprocessor 35 and is used to produce the required pulse signals TX, TG1, TG2 and T_{latch} to each of the components described above (shown in Figure 7), wherein:

TX represents the main input pulse to the pulse producer;

The SO2 pulse signal is used to control the time sequence of emissions by the laser emitter 10;

The TG1 pulse signal eliminates the interference produced between the laser emitter 10 and the laser receiver 21 at the time of laser emissions; and

The TG2 pulse signal is used to control the gate-in time (Gated-in Time) segment of the gate control counter 23, and in this practical example the sampled gate width is equal to the maximum measurable range;

The T_{latch} pulse signal controls the locking speed of the information locking device 31;

Figure 6 shows the function of the fixed false alarm rate element 20, the operating principle of this element being explained as follows:

In Figure 6 this element is connected to an avalanche detector APD 25 (Avalanche Photo-Detector) used for receiving the input light signal, this avalanche detector 25 biased at a negative V_{EE} voltage, enabling it to produce 100 internal increases, a transfer impedance amplifier (Transimpedance Amplifier) 211 which converts the output current signal from the detector to a voltage signal output, the output signal being SO1, which is transmitted to the high-speed comparator 212, the output of the high-speed comparator 212 being transmitted to the one-shot circuit (One-shot Circuit) 213 used to obtain the fixed pulse width digital pulse series, the output signal of this one-shot circuit 213 being SO2. This is controlled by the gate control signal TG1 by means of an AND gate (AND Gate) 214, used to eliminate the instantaneous interference between the laser emission and the light receiver 21, the output signal SO3 of the AND gate 214 being fed into the information locking device 31 and the gate control counter 23. The gate control counter 23 is used to calculate the number of SO3 pulse waves in the gate time (gated time) segment controlled by the pulse signal TG2;

The analogue signal output by the D/A converter 24 and the number of SO3 pulses in the gate time (gated time) segment controlled by TG2 are the same.

Figure 7 shows the interrelations between the sequential signals TX, SO2, TG1, TG2 and T_{latch}. TX is used to trigger the laser emitter 10, SO2 is the output signal from the one-shot circuit 213, the sample time T500 SO2 signal is the target signal, and the sequential signal TG1 has a pulse width of TW1 and is used to eliminate the interference between the laser emission and the signal SO2. In this practical example, therefore, a range shorter than the pulse width TW1 cannot be read. The sequential signal TG2 has a pulse width of TW2 and is used for sampling the gate control counter 23.

Figure 8 is a schematic diagram of the function of the rangefinding element 30. The serial signal SO3 is fed into the information locking device 31 by the high-speed sampling signal T_{latch}, and the output signal SO4 from the information locking device 31 is a parallel output D_0 to D_N. The signal SO4 passes through the multiplexer (N to 1) 32 which is controlled by the low-speed sampling signal T_{mux}, and the decoder 322 is used to produce the low-speed

sampling signal T_{mux} for controlling the multiplexer 32. The output signal SO5 from the multiplexer 32 is read by the microprocessor 35; and the program in the microprocessor 35 stores the SO5 information D_0-D_N in sequence in the storage device 33.

Summarizing the above, it can be seen that the present invention uses a servo control loop technology to increase the sensitivity of a light receiver by endowing the laser light receiver with a fixed false alarm rate; it uses a pulse series reflection address method to enable this laser rangefinder to seek out the target signal in the presence of clutter; a signal and clutter digital integration method is used to filter out the clutter and amplify the signal; in summary, the technology disclosed in this invention can increase the measurable range of a laser rangefinder without increasing the power of the laser emitter and can make the range measurement more precise; furthermore, this invention increases the target measurability by increasing the number of emissions to increase the range to be measured without increasing the emission power.

Appended Figures to Description

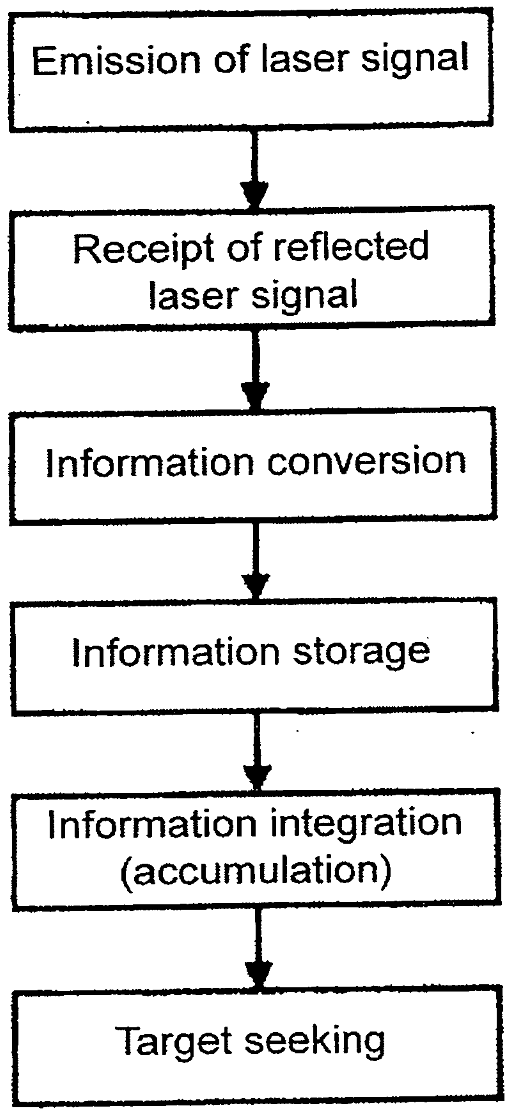


Figure 1

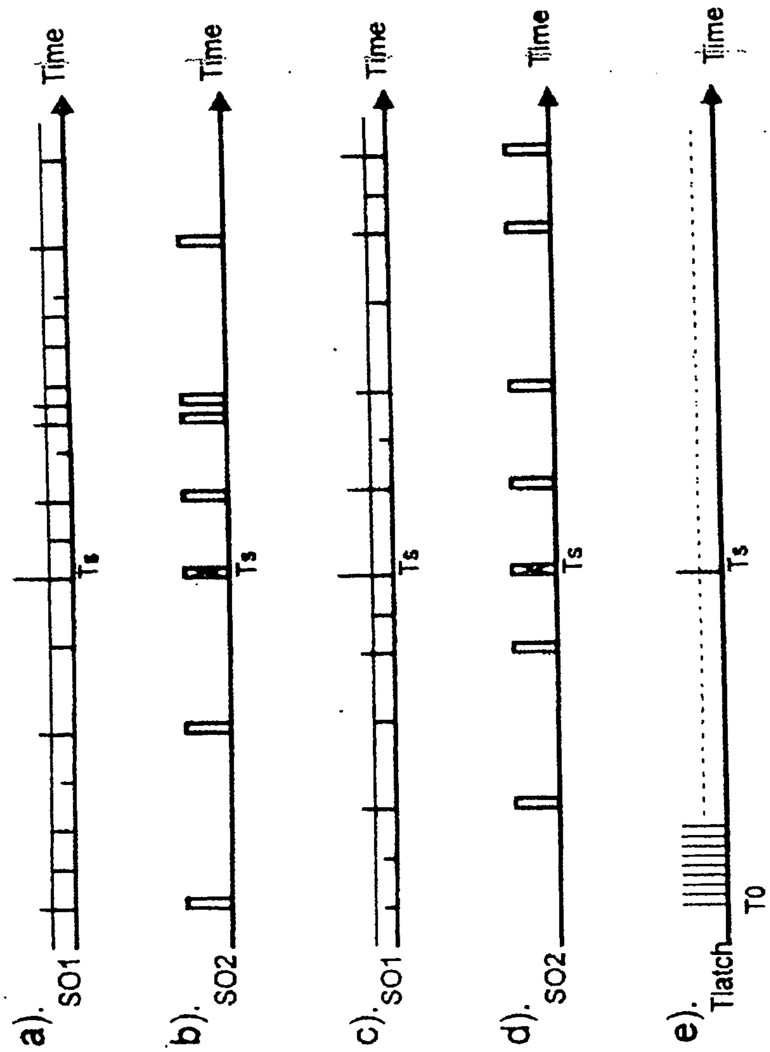
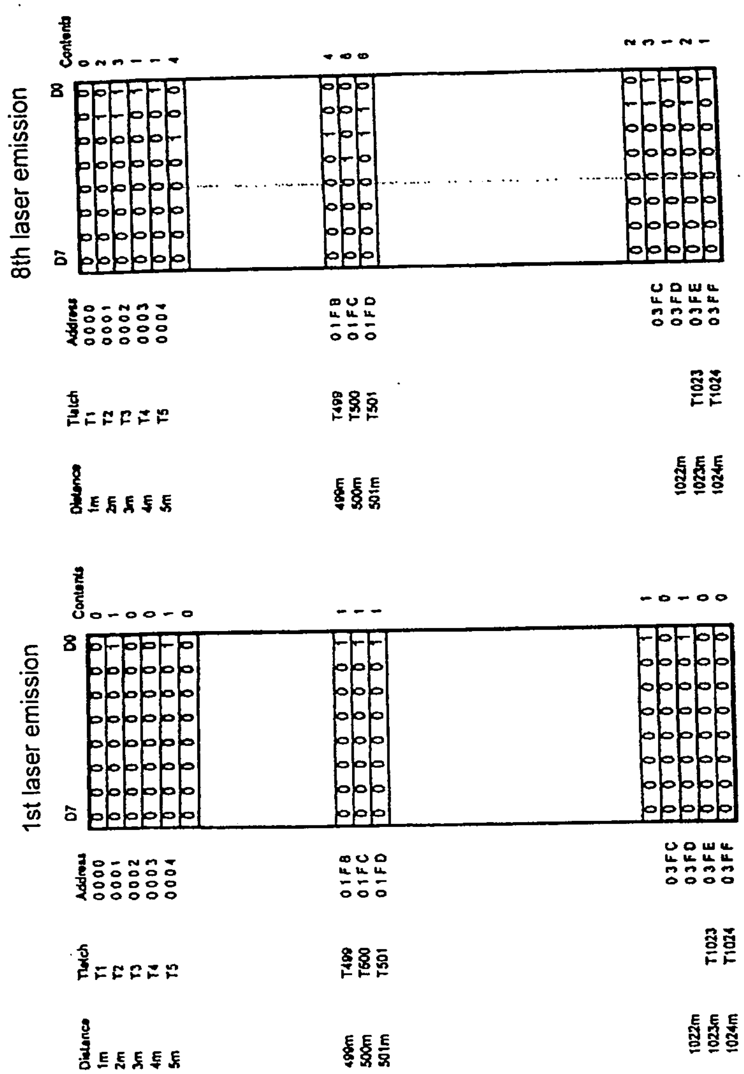

a).
SO1
Ts
Time
b).
SO2
Ts
Time
c).
SO1
Ts
Time
d).
SO2
Ts
Time
e).
Tlatch
T0
Ts
Time

Figure 2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1st laser emission
Distance
Tlatch
Address
D7
D0
Contents

Figure 3

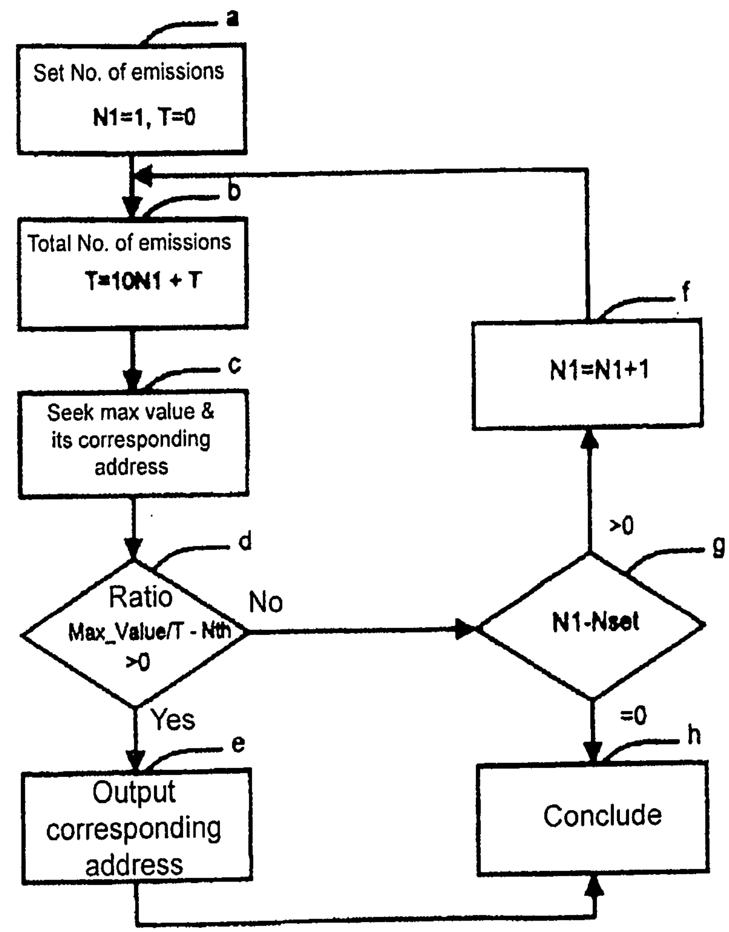

a
Set No. of emissions
N1=1, T=0
b
Total No. of emissions
T=10N1 + T
c
Seek max value & its corresponding address
d
Ratio
Max_Value/T - Nth
>0
Yes
No
e
Output corresponding address
f
N1=N1+1
>0
g
N1-Nset
=0
h
Conclude

Figure 4

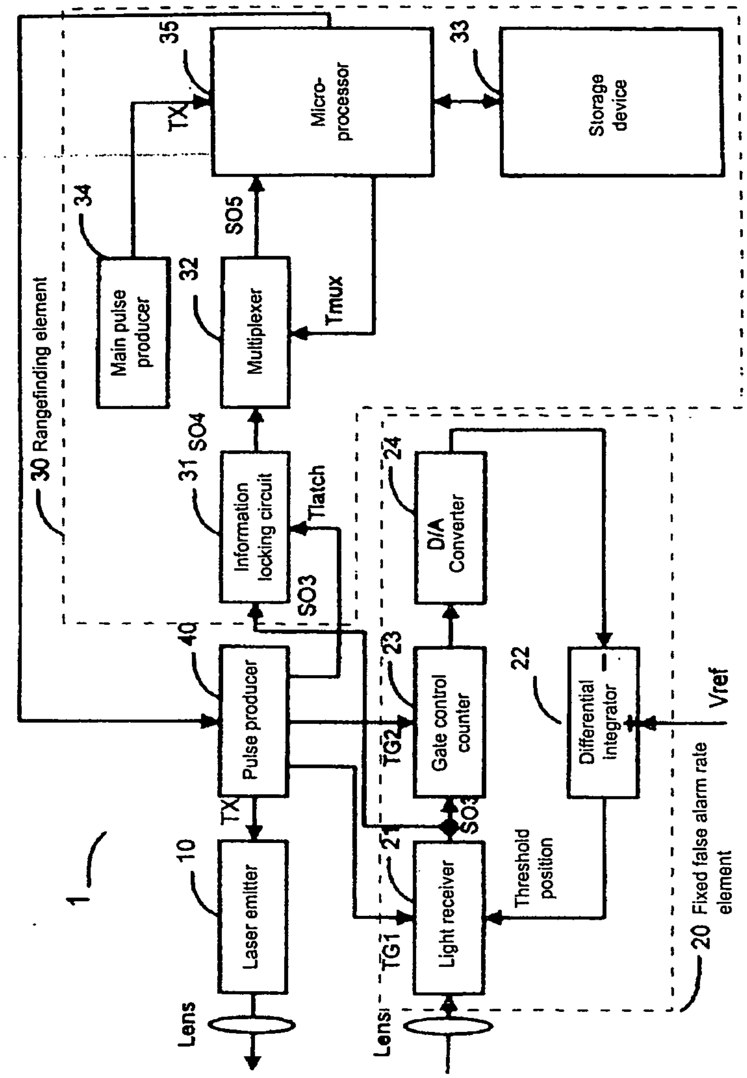

1
10
Laser emitter
Lens
TX
40
Pulse producer
30 Rangefinding element
31
Information locking circuit
SO4
SO3
Tlatch
32
Multiplexer
Tmux
SO5
34
Main pulse producer
35
Micro-processor
TX
33
Storage device
20 Fixed false alarm rate element
21
Light receiver
TG1
Lens
Threshold position
23
Gate control counter
TG2
SO3
24
D/A Converter
22
Differential integrator
Vref

Figure 5

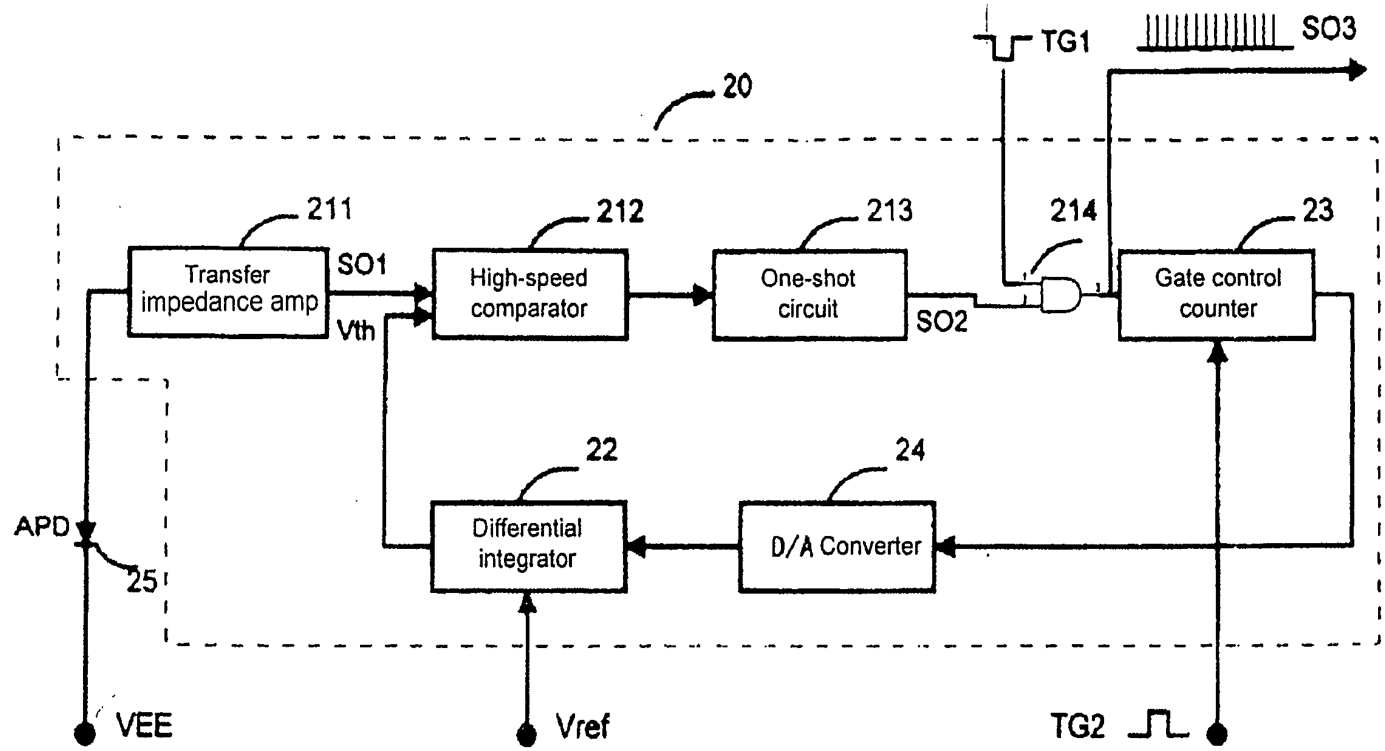

20
211
Transfer impedance amp
SO1
Vth
212
High-speed comparator
213
One-shot circuit
SO2
214
TG1
SO3
23
Gate control counter
22
Differential integrator
24
D/A Converter
APD
25
VEE
Vref
TG2

Figure 6

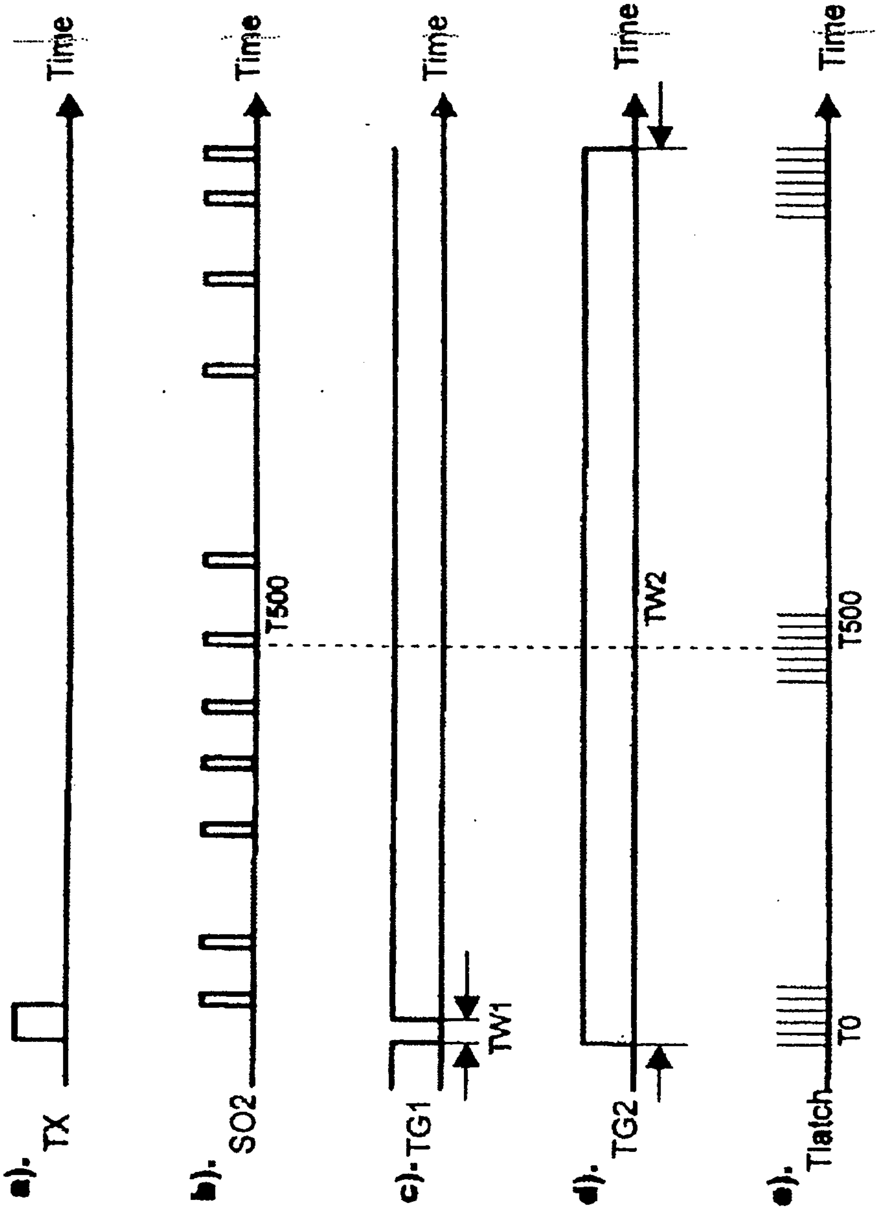
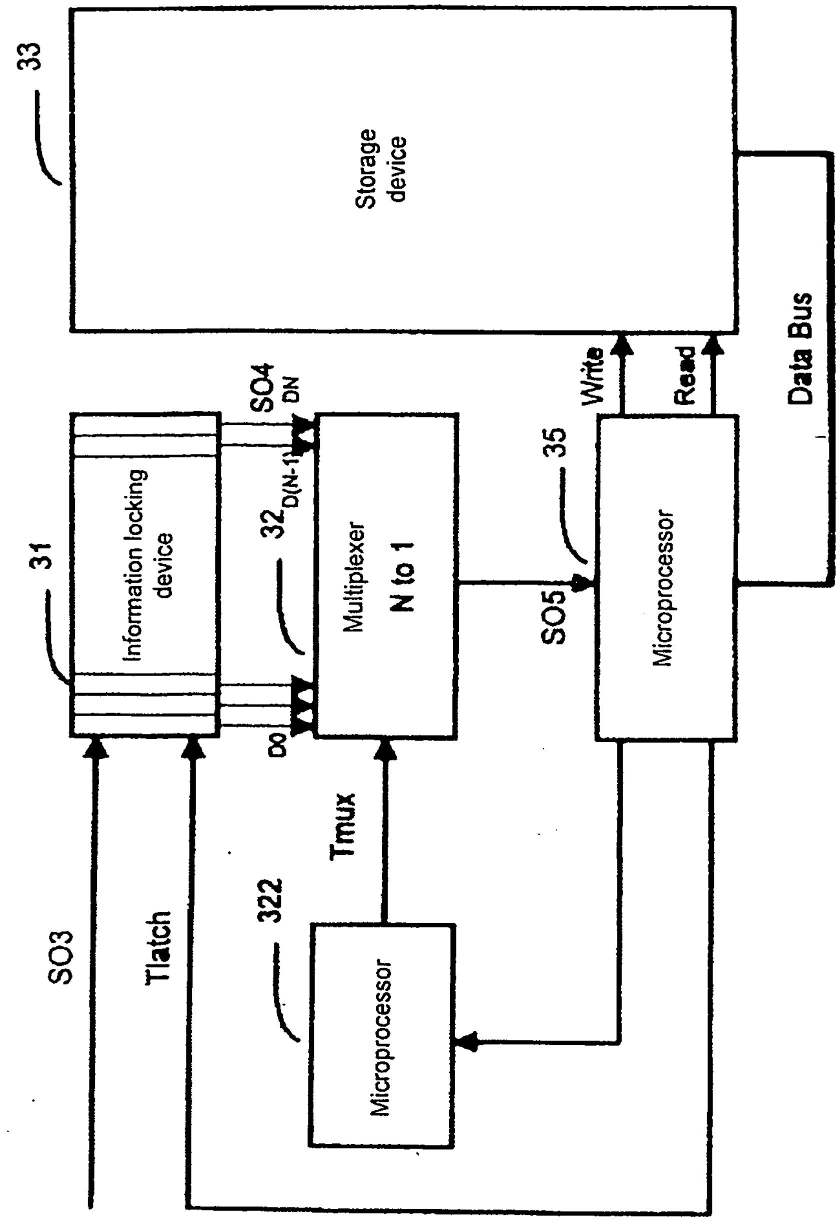

a). TX
b). SO2
c). TG1
d). TG2
e). Tlatch
Time
Time
Time
Time
Time
T500
TW1
TW2
T500
T0

Figure 7



33
Storage device
31
Information locking device
32
Multiplexer
N to 1
SO4
DN
D(N-1)
D0
SO3
Tlatch
Tmux
322
Microprocessor
35
SO5
Microprocessor
Write
Read
Data Bus

Figure 8